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THE EFFECT OF TIRE CHAINS ON WHEELED VEHICLE MOBILITY

October 1966

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by P. W. Haley
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Land Locomotion Laboratory

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THE EFFECT OF TIRE CHAINS

ON WHEELED VEHICLE MOBILITY

By: P. W. Haley
Z. J. Janosi

October 1966

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ABSTRACT

The effect of tire chains on the off-road performance of wheeled vehicles has been investigated.

Comparative tests have been run under "hardpan" conditions and on dry firm ground.

It was found that chains contributed to a significant improvement to the traction on hardpan, but they proved to be unnecessary on uniform soils.

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LIST OF SYMBOLS

d_T Theoretical Distance "Covered" by the Vehicle . . . . (Ft.)

$D/2$ Rolling Radius of Tire . . . . (Ft.)

n Number of Wheel Revolutions

i Slip

v_T Theoretical Velocity . . . . . (Ft./Sec.)

v_a Actual Velocity . . . . (Ft./Sec.)

t Time . . . . . (Sec.)

LIST OF FIGURES

INTRODUCTION

The Land Locomotion Laboratory was directed in June, 1965, by the Chief of the Components Research and Development Laboratories, U, S. Army Tank-Automotive Center, to evaluate the effect of tire chains on the off-the-road performance of wheeled military vehicles. The application of chains was expected to improve the performance of the vehicle by increasing its traction.

Traction is the resultant force of the shear stresses created under the tire. When the soil "sticks" to the tire, shear stresses occur between two soil layers along the so-called surface of shear failure below the soil surface. The magnitude of the stresses is limited by the normal load and the strength of the soil.

According to observations, however, "tractive shear stresses" often occur at the surface of the tire. In this case traction is defined by the adhesive properties of the material of the tire and the soil. It is clear that actual traction will be developed by the smaller of these two strength values.

The Land Locomotion Laboratory has recently started to use rubber-coated shear annuluses in addition to conventional metal footings for the establishment of soil shear strength parameters to account for the above conditions. There is no theoretical argument which would support the assumption that certain tread configurations or chain designs would significantly improve the tractive properties of a tire operating in homogeneous soft soil conditions. The significance in tire tread design is related to the self-cleaning characteristics of the tire. A directional tread on a tire does not improve performance because of the directionality of the tread. It improves performance by providing optimum self-cleaning so that full use of soil shear strength is possible.

Certain tests (1) demonstrate that in sand, smooth tires have higher traction than similar tires with lugs. The improvement was observed at lower slips. There was no significant difference, however, in the maximum tractive forces as opposed to maximum drawbar forces. One reason for this "unexpected" phenomenon is that lugs make the tire stiffer so that it sinks deeper into the soil due to higher ground pressure and as a result encounters higher resistance.

When a soft slippery layer of soil or snow covers a hard surface, however, the increased contact pressure allows the tire to sink to the firmer surface whose superior strength may mean the difference between a "Go" or a "No-Go" situation. This is why tire chains are useful on snow-covered terrain, in rice paddies, and in some tropical forests where a thin slippery "lubricant" soil layer covers very firm ground.

OBJECT

The object of this work was the establishment of the effect of tire chains on wheeled vehicle traction on soft terrain. It is known that chains improve the mobility of vehicles when roads are covered with snow. The question whether the improvement is significant under adverse soil conditions in general, had to be answered in conjunction with the task described in this report.

SUMMARY

Three wheeled vehicles of various load carrying capacities underwent drawbar-pull tests. The tests were performed with and without chains. The test site was covered with sandy loam which is firm when dry and relatively "soupy" when wet. A soil layer of high clay content was underneath the sandy-loam cover. Thus, when the top layer was wet, a "hardpan" condition was present similar to the combination of soil layers present in rice paddies or in most jungles.

Test results indicated that the traction of a wheeled vehicle is significantly improved by tire chains if a "slippery" layer of soil covers a firm layer. The chains grip into the firm layer provided inflation pressure and load allow a deep enough vehicle sinkage. It was found, however, that tire chains have no useful effect under deep uniform soft-soil conditions.

TESTS

In order to evaluate the effect of tire chains on performance, a series of field tests was undertaken by the Land Locomotion Laboratory in July, 1965. The following three vehicles were chosen for the test program: a 1/4 ton, M-38A1; a 3/4 ton, M-37; and a 5-ton, M-51 Dump Truck. Although the selection was restricted by availability of vehicles, the three vehicles represent a wide range in weight and load-carrying capacity.

Since interest was focused on traction increased by the use of chains, drawbar-pull measurements were chosen as the basis of evaluation. Drawbar-pull tests are used to establish the margin of traction available under any given soil conditions. The "extra traction" may be utilized for negotiating slopes or for pulling a trailer. Although the majority of the military vehicles are not intended to pull a trailer, the drawbar-pull-weight ratio is still an important parameter in the evaluation of the off-the-road performance of a vehicle. A high drawbar pull to weight ratio means that soil strength is efficiently utilized by the running gear and hence the vehicle could move on a weak soil which would immobilize another vehicle of lower drawbar-pull to weight ratio.

Drawbar-pull is measured as a function of slip. The simultaneous measurement of slip and drawbar-pull is necessary for the evaluation of the efficiency of the vehicle-soil system. If two vehicles demonstrate the same maximum drawbar-pull, the one which attains the maximum at a lower slippage is preferable because slip results in energy losses. It should be emphasized, however, that for military applications a vehicle with a higher maximum drawbar pull-weight ratio is preferred in spite of higher fuel consumption or higher wear on the tires. Agricultural engineers, on the other hand, are strongly concerned about economical operation, and hence, substantial pull at low slip rates. Low slip is also emphasized in agriculture because high slippage destroys the structure of the soil and it is detrimental to plant growth.

The test site was located near the Keweenaw Field Station in Houghton, Michigan. It consisted of a 12-inch layer of firm sandy-loam which covered a hardpan of clayey-sand.

The test course was 300-feet long and 60-feet wide.

The test vehicles were equipped with revolution counters on each powered wheel to record slippage. To measure drawbar-pull, the vehicle pulled a dynamometer vehicle by means of a cable to which a load cell was attached. The test vehicle was driven at full throttle in the lowest gear and the dynamometer load increased in increments until 100% slip occurred. Each test was repeated three times. Since three vehicles were tested with and without chains, eighteen test runs were made.

The drawbar-pull and the RPM of the powered wheel were recorded continuously, along with the speed of a "Fifth wheel". It is fortunate that the data demonstrated negligible differences between the slip values of the wheels on each side of the vehicle at any particular drawbar-pull level for each test condition. Thus, the arithmetic averages of the simultaneous slip readings for both wheels were taken as the slip readings.

Care was taken to assure that the cable connecting the vehicle and the dynamometer remained horizontal during the test run in order to produce a true drawbar-pull reading and not require a trigonometric correction for the inclination of the cable. The instrument technician who observed the recorders guided the operator of the dynamometer to produce constant pull and slip for an extended period. This was necessary because the drawbar load indicator located in the dynamometer operator's cab was inoperative.

EVALUATION OF DATA

The evaluation of the data required a straightforward, but somewhat tedious, procedure.

The load cell-recorder system was calibrated, and the pull reading appeared as an ordinate on the recording paper. Because of variations in soil conditions the load reading was not absolutely constant over the distance through which the operators attempted to keep the force at a certain level. By using a planimeter, however, the average ordinate could be established easily. This ordinate was then converted to force by means of the calibration curve.

The slip was measured by means of a micro-switch activated by a hexagonal cam which was fastened to the axis of the wheel. Thus, one full revolution of the wheel caused six "pips" on the paper. Since the speed of the paper was constant, the number of pips on a given paper length indicated wheel RPM. Since the diameter of the tire was known, the theoretical distance covered while the length of the paper passed through the recorder was easily obtained:

$$d_T = D \pi n$$

where d_T is the theoretical distance, D is the diameter of the tire and n is the number of wheel revolutions. The latter was equal to the number of pips divided by six.

The actual distance covered was established by means of a fifth wheel which had the same instrumentation as the powered wheels of the vehicle.

Slip is defined as

$$i = \frac{v_T - v_a}{v_T}$$

where v_T is the theoretical velocity and v_a is the actual velocity. If the number of wheel pips and "fifth wheel" pips are established over the same stretch on the recording paper then

$$i = \frac{\frac{d_t}{t} - \frac{d_a}{t}}{\frac{d_t}{t}} = \frac{d_t - d_a}{d_t}$$

where t is the time defined by the speed of the recording paper and the length of the stretch mentioned above. It is emphasized that the frequency of pips should be as close to uniform as possible within the paper length considered.

CONCLUSIONS

The soil was dry on the first day of the test series. Figures 1 and 2 show that there was very little difference between the drawbar pull of the vehicle equipped with chains and that of the same vehicle having no tire chains. The M-51 dump truck could not be tested under dry soil conditions because of the lack of time. It is felt, however, that the results obtained by testing the M-38A1 and the M-37 vehicles strongly indicate that the absence of any difference due to the presence of chains was not mere coincidence.

The field was flooded and drained after the first day so that the moisture content increased to 21% by the second day of testing. Repeated test runs with the same vehicles demonstrated a very significant improvement in traction when chains were mounted on the tires, Figures 3 and 4.

By the fourth day of testing, 15 July, the moisture content dropped to 17%. Tests with the M-51 did not produce any significant difference between "bare" tires and those equipped with chains.

The following conclusions can be drawn from the test results:

1. When a shallow layer of soft, "slippery", soil covers a harder layer, the use of tire chains improves the traction of the vehicle. Such conditions prevail on most snow-covered fields, in tropical jungles, and rice fields.

2. Under uniform soil conditions, tire chains are not useful.

3. The mounting of tire chains on vehicles equipped with dual tires or on vehicles having more than four wheels requires considerable time and effort.

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Vanden Berg, G. E., and I. F. Reed, "Tractive Performance of Radial and Conventional Tractor Tires", Paper No. 61-608, Winter Meeting of the American Society of Agricultural Engineers, Chicago, 1961.

KEWEENAW FIELD STATION
7 July 1965
M37, 3/4 Ton
w = 7,300 lbs.
P_i = 30 psi
DP/W vs. Slip

DRY LOAM

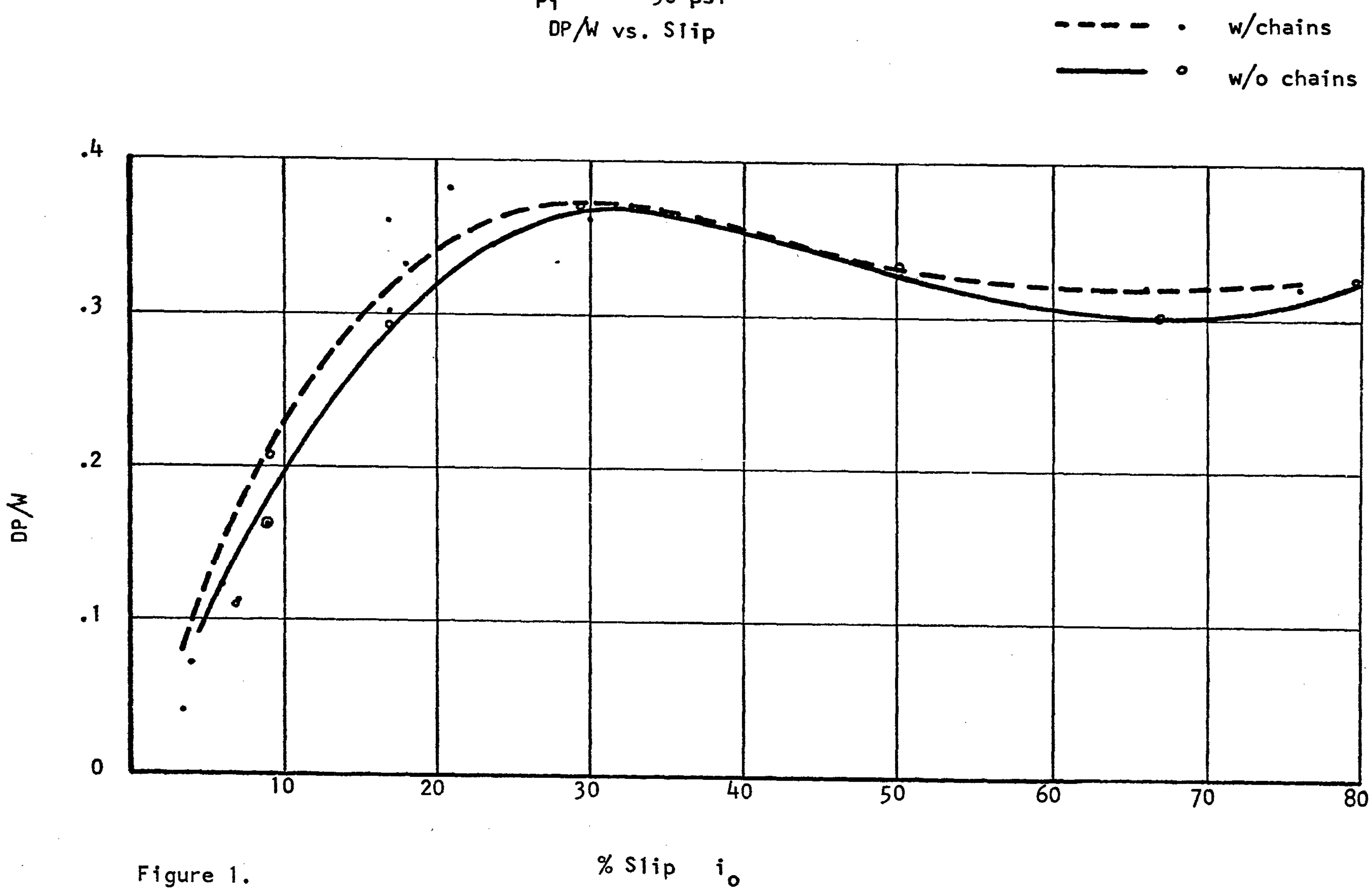

Figure 1.

KEWEENAW FIELD STATION

7 July 1965

M-38A1, 1/4 Ton, JEEP

$W = 3,600$ lbs.

$p_i = 25$ psi

DP/W vs. Slip

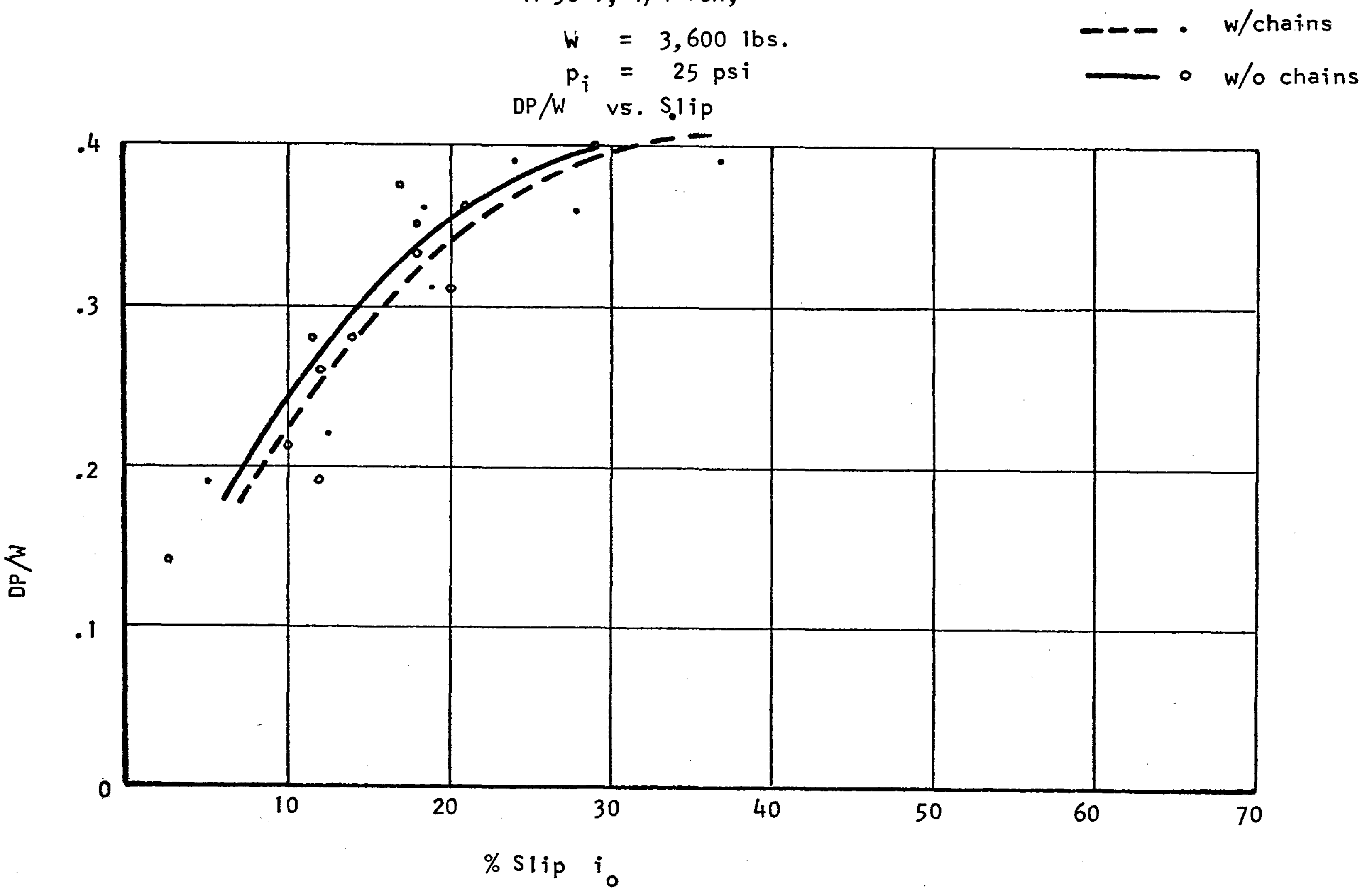

Figure 2.

KEWEENAW FIELD STATION

12 July 1965

M-38A1, 1/4 Ton, JEEP

w = 3,600 lbs.

P_i = 25 psi

DP/W vs. Slip

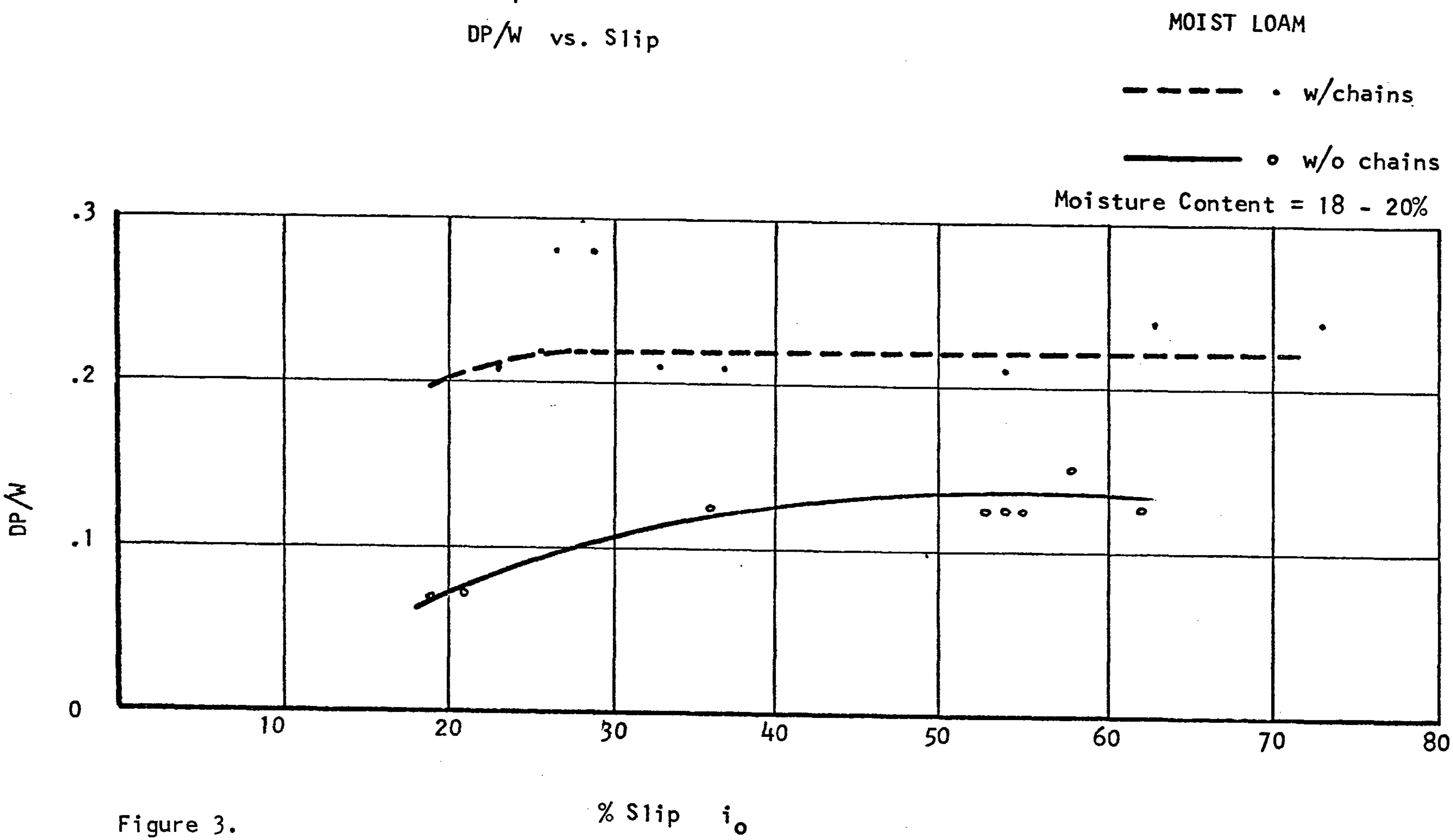

Figure 3.

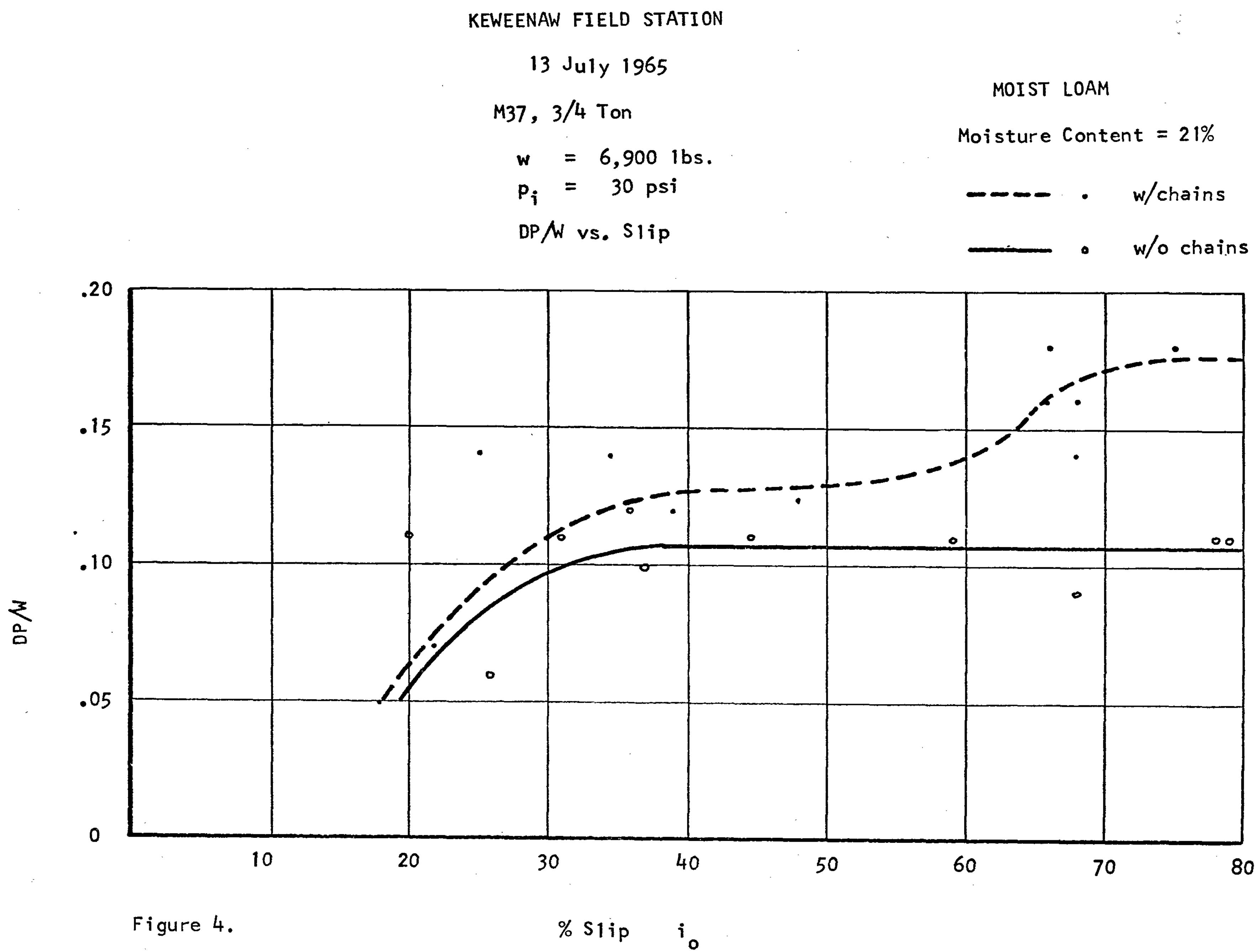
KEWEENAW FIELD STATION
13 July 1965
M37, 3/4 Ton
w = 6,900 lbs.
p_i = 30 psi
DP/W vs. Slip
MOIST LOAM
Moisture Content = 21%
w/chains
w/o chains
.20
.15
.10
.05
0
DP/W
10
20
30
40
50
60
70
80
% Slip i_o

Figure 4.

KEWEENAW FIELD STATION

15 July 1965

M-51, 5 Ton, Dump Truck

w = 31,900 lbs.

P_i = 60 psi

DP/W vs. Slip

MOIST LOAM

Moisture Content = 17 - 20%

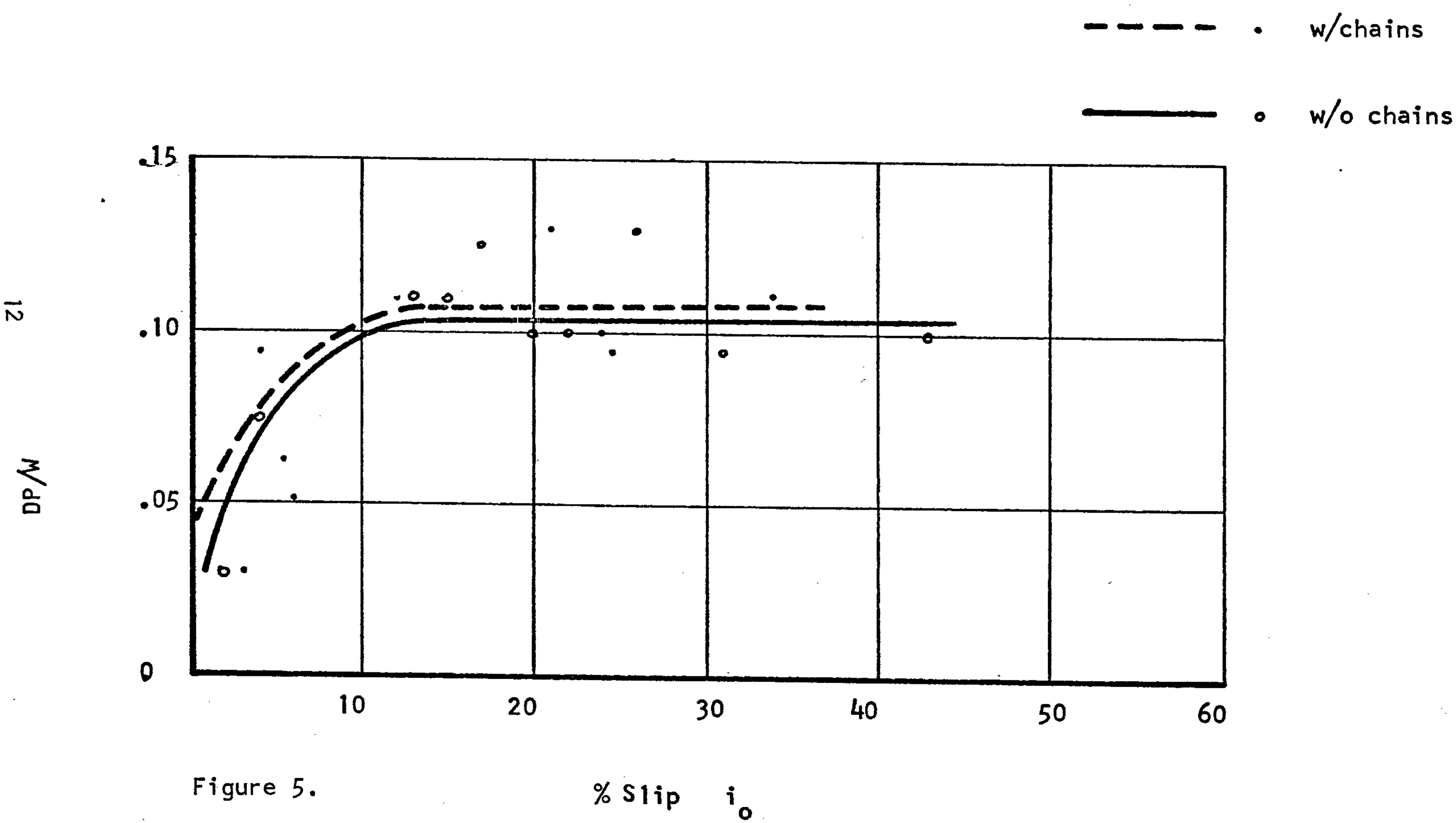

Figure 5.

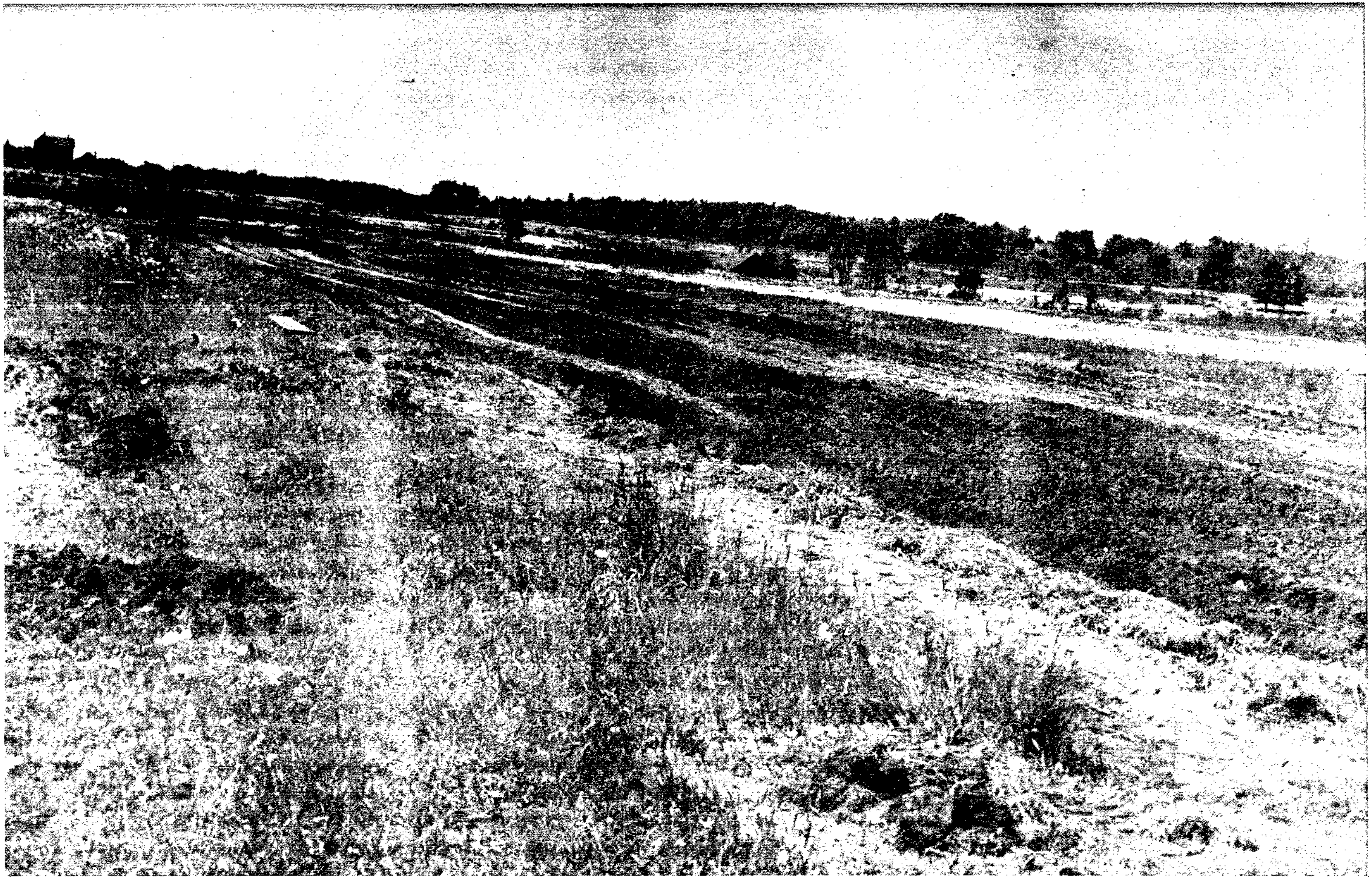

Figure 6 Overall View of Test Area.

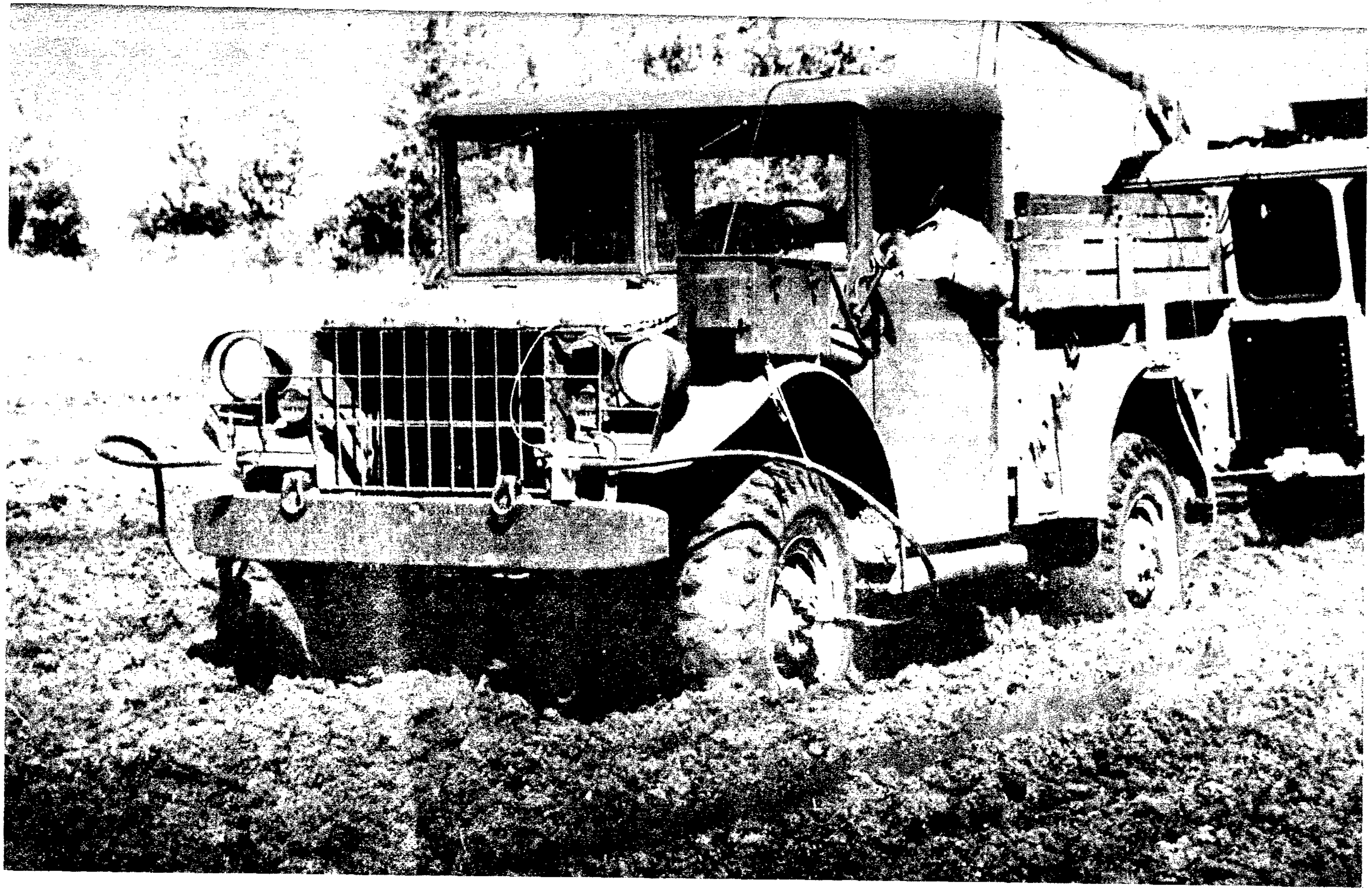

Figure 8. M-51 Being Prepared for Testing.

Figure 7. M-37 Truck During a Test Run.

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DRAWBAR PULL TESTS						
EFFECT OF "SLIPPERY" TOP LAYER						
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